National Renewable Energy Laboratory
Innovation for Our Energy Future

Western Wind and Solar Integration Study: December TRC meeting

Greg Brinkman
Debbie Lew

National Renewable Energy Laboratory
Golden, Colorado USA

Outline

1. Status
2. Retirements
3. Hydro dispatchability proposal
4. Reserves proposal
5. Transmission expansion

Status update

- First iteration of solar data complete (with delays)
- APTECH is finalizing cycling cost estimates
- Imported wind/PV/CSP generators for high-wind scenario
- Created zonal model for 21 WECC LRS zones
- Added policy-driven generator retirements

To do:

- Update hydro flexibility inputs
- Perform transmission expansion on high-wind scenario
- TRC to review draft of transmission expansion
- Update methodology as necessary
- Apply to other scenarios

Retirements

Identified units not retired in our base case but retired on TEPPC 2022 assumptions:

- Actual retirements (pre-2011).
- Expected due to policy/economics (post-2011).

Effective retired capacity (5.6 GW) will be replaced by CC/CT ("Repower scenario").

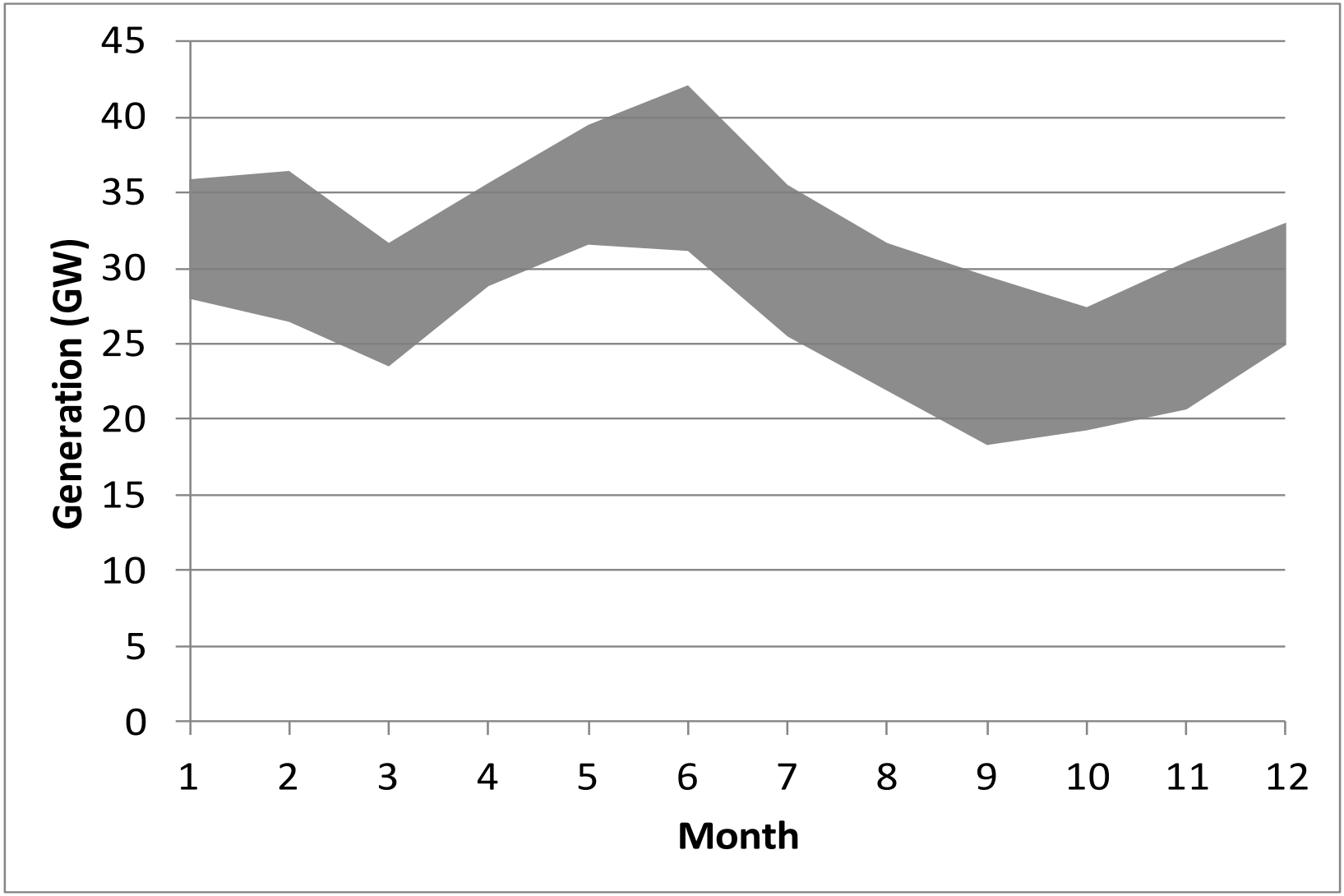
- Assumptions already include 3 GW with location.
- The rest will be placed based on retirements and/or system adequacy needs.

Hydro dispatchability

•Hydro defined as “flexible” or “inflexible” based on WECC TEPPC hydromodeling task force work

	Flexible	Inflexible
Annual generation	111 TWh (US)	70 TWh (US)
Dispatch	Optimized by model	Actual 2006 profile
Min/max generation limits	Limited by: 1. TEPPC-provided hourly max capacity 2. TEPPC-provided minimum generation 3. Monthly maximum and minimum values using PLF algorithm	N/A
Ramp rates	From TEPPC if available or 5%/min?	N/A
Ancillary services?	Yes, within bounds of ramp rate and min/max generation	No

Hydro dispatchability

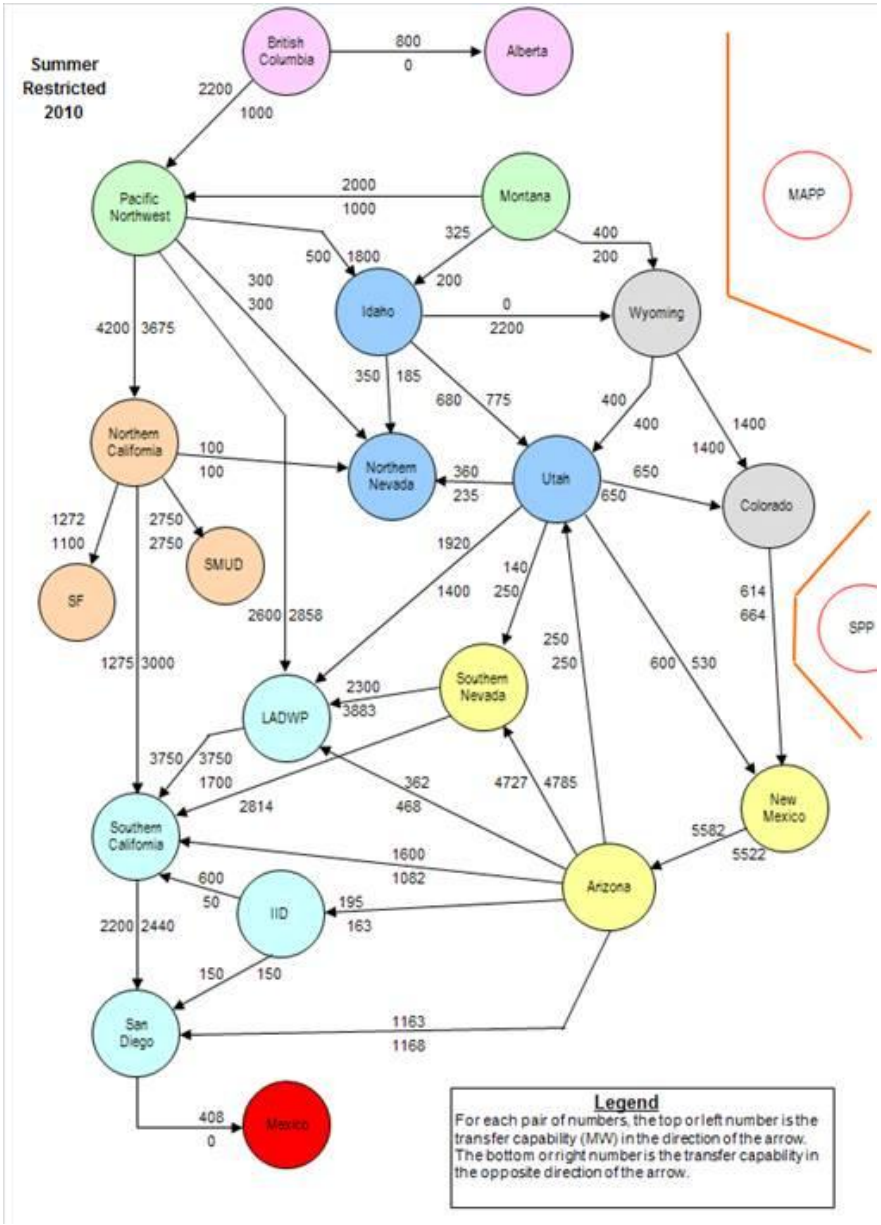


Reserves

Type	Regulation	Flex	Conventional
Purpose	Sub-dispatch interval changes in net load	Load, wind, and solar forecast error	Contingencies
Time resolution	5-min	??	10-min
Reserve Sharing Group Size	All of WECC (represents RBC)	21 WECC LRS zones	21 WECC LRS zones
Methodology	Analysis of net load variability	Analysis of wind, solar, and load variability (e.g., EWITS)	Similar to today

Model up-reserves only

Reserves



- Reserve sharing areas for flex and contingency reserves
- Regulation will share throughout WECC to represent Reliability-Based Control (RBC)

Transmission expansion

- Assume both existing and new transmission is used optimally
- Perform transmission expansion on high-wind scenario
- TRC to review draft of transmission expansion
- Update methodology as necessary
- Apply to other scenarios

- Currently seeking ideas, questions, and comments/concerns on our ideas

Transmission expansion

How to choose where to build?

- LMP differences
- Congestion cost
- Shadow price of interface constraints
  - Won't show "depth of market"
- Add reasonable (e.g., $10-$100/MWh) "penalty cost" for violation of existing line limits
  - Build as much additional capacity as is used for X hours per year
- Might require iterations

Transmission expansion

When to stop?

- Transmission is system optimal based on rule-of-thumb transmission cost
  - i.e., production cost goes down by more than the cost of transmission
- Curtailment reaches a “goal” value
- % increase in zonal transmission limits?
- Some combination of the above

- Does it need to be quantitative?

Questions?

Greg Brinkman

303-384-7390

gregory.brinkman@nrel.gov

Debbie Lew

303-384-7037

debra.lew@nrel.gov

Next TRC probably late Jan or early Feb to discuss initial results from transmission buildout runs and confirm methodology

Renewable generation profiles

Solar

- Remake all solar generation data, down to 1-min resolution
- PV is 60% of solar, CSP is 40%

Distribution to regions based on the ReEDS results

Distribution within regions based on the following rules:

- Rooftop PV is 40% of PV where possible
  - Capacity distributed by population (same capacity per person)
  - Maximum capacity per grid cell of 1 kW/person
  - All scenarios use same sites with different capacity per grid cell
- Distributed utility PV is ~20% of PV
  - Sited near population areas
  - Scenarios use subset of sites
- “Remote-site” utility PV is 40% of PV
  - Sited based on capacity factor
  - Scenarios use subset of sites

Renewable generation profiles

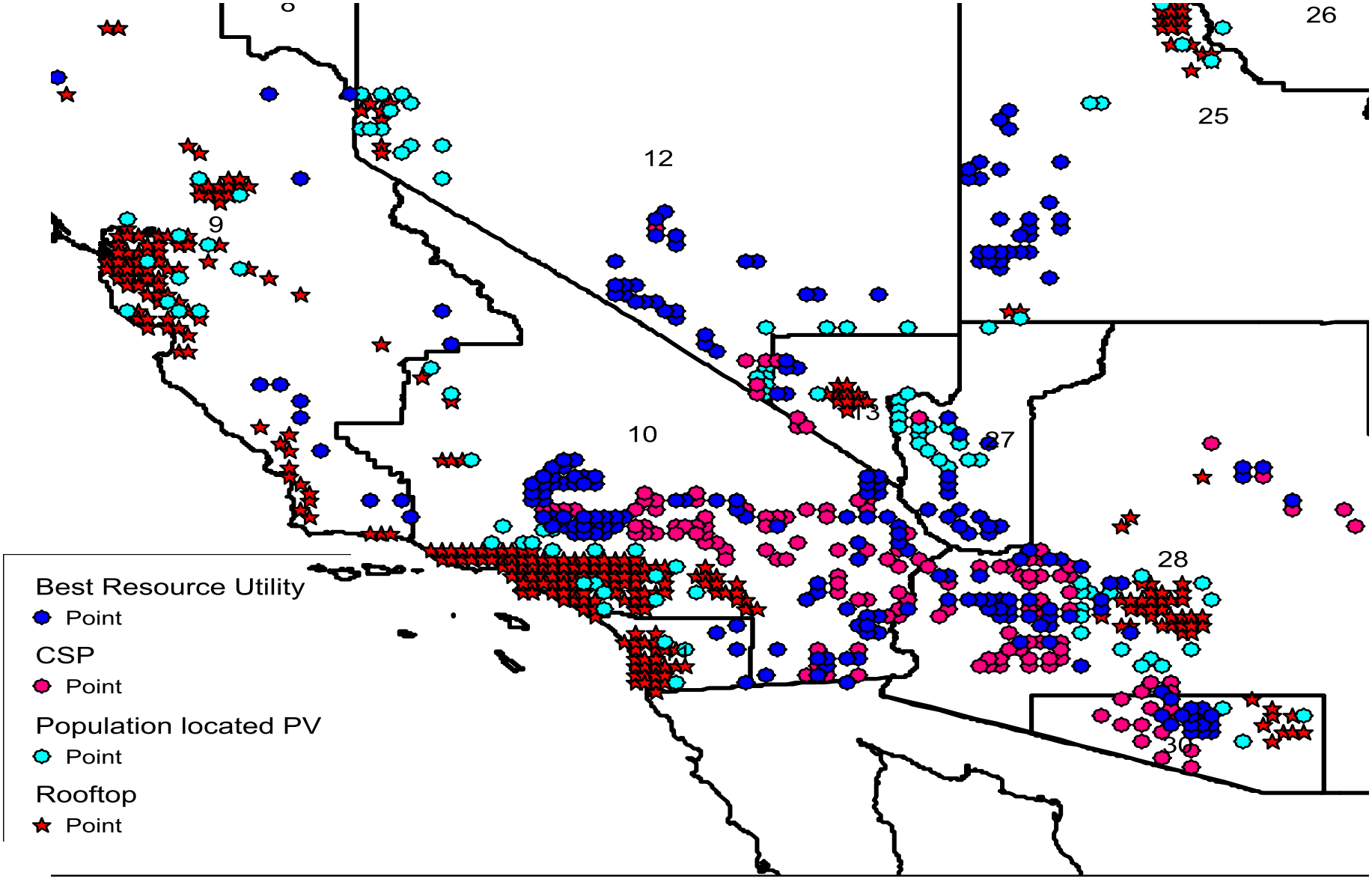
Wind

- Sited by capacity factor within ReEDS region
- Close capacity factor sites were sometimes substituted so not all wind was in same location
- Use WWSIS phase 1 data set
- Statistically downsampled data available for subhourly analysis

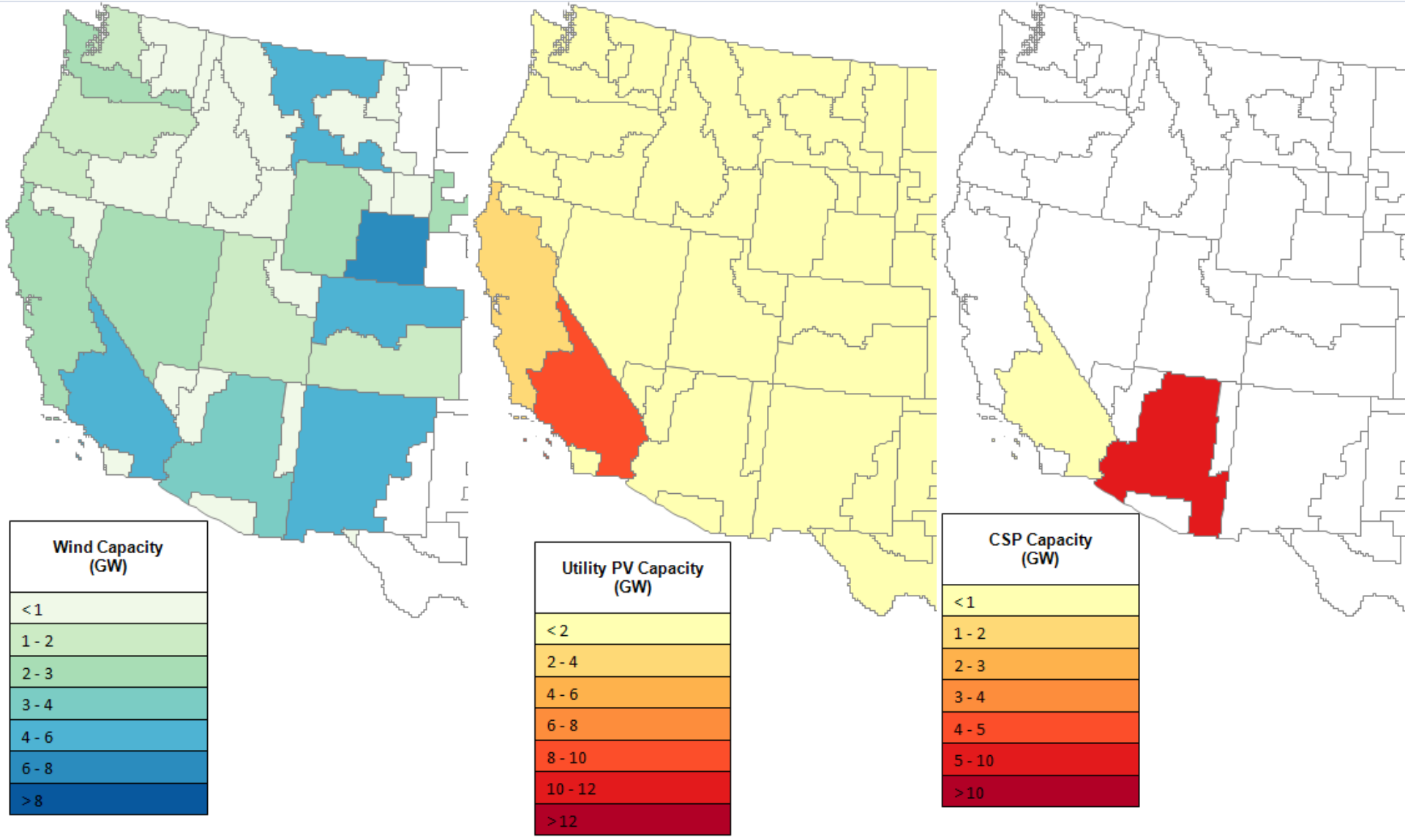
Load

- 2006 1-min data available from WECC VGS
- 2004 or 2005?

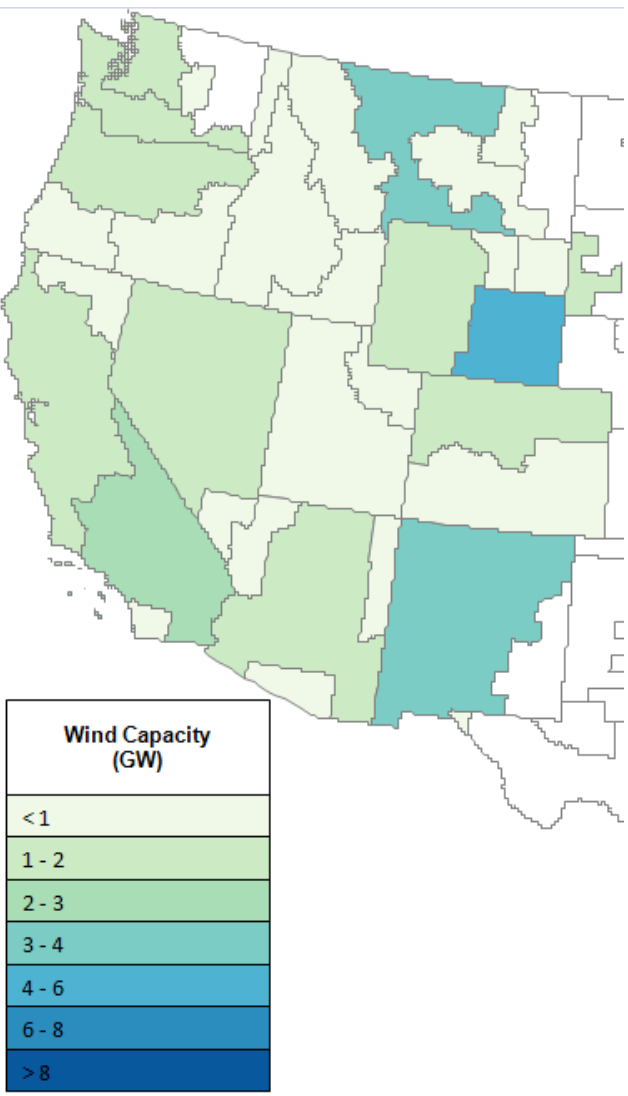
Sample map of solar sites

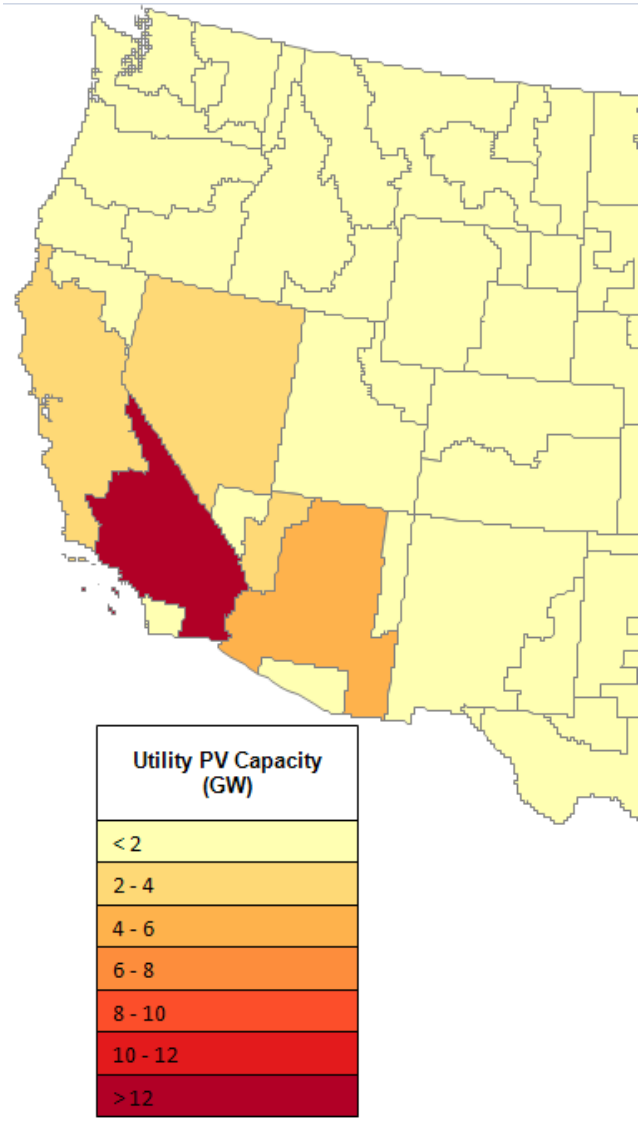


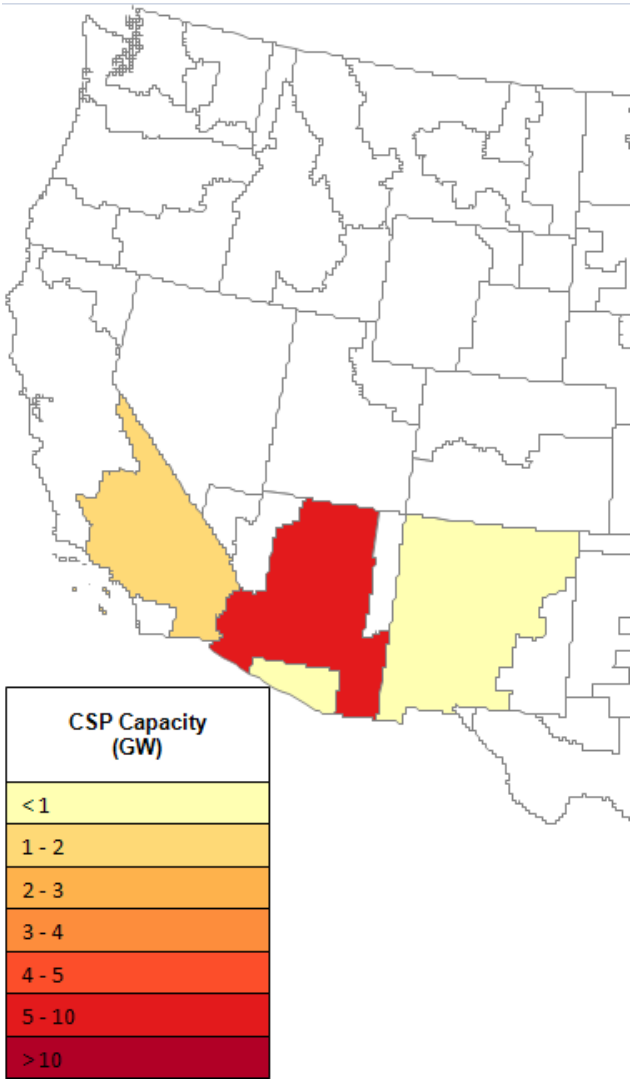
High wind (25% wind, 4.8% PV, 3.2% CSP)



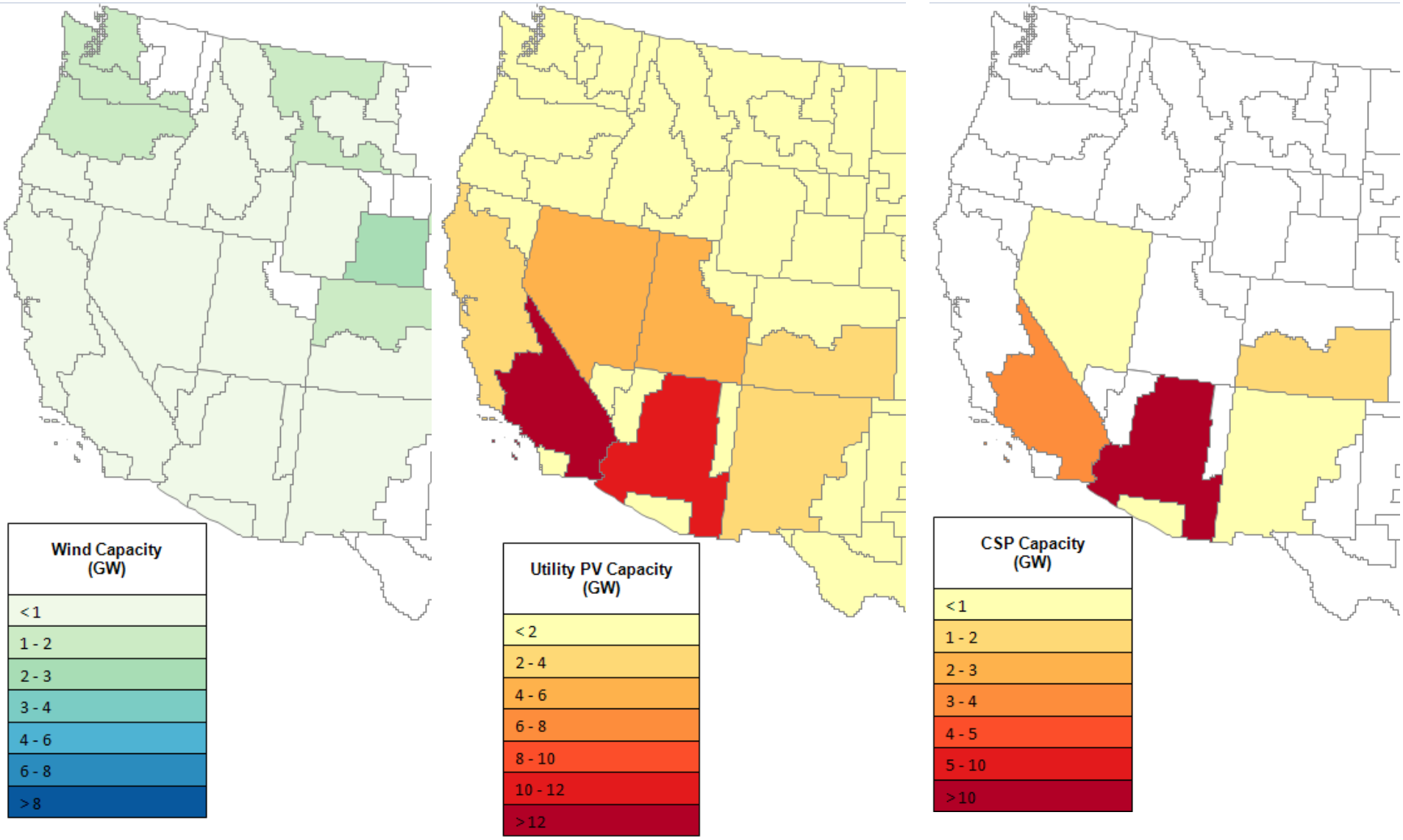
Intermediate (16.5% wind, 9.9% PV, 6.6% CSP)







High solar (8% wind, 15% PV, 10% CSP)



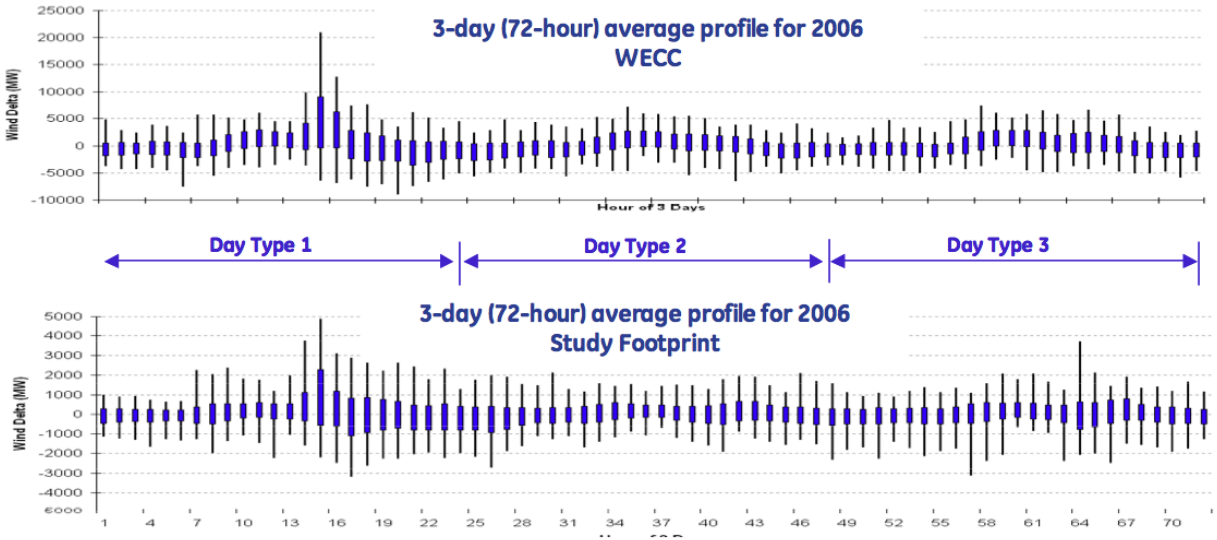
Choosing buses to inject renewables

- Bus location data from Energy Visuals, Inc.
- Remote-site resources
  - Sited to nearest bus >=230 kV
  - No limit on renewable injection (MW) per bus
    - Transmission buildout should solve overloaded line problems
- Rooftop PV, distributed UPV
  - Distribute by load distribution factors for each load zone

3-day seam fix

3TIER Western Wind Resources Dataset

- Increased variability at 3-day seams – was not found to be a problem with hourly MAPS simulations in WWSIS1. Every 3rd day was removed from statistical analysis in WWSIS1
- Jack King has re-analyzed the dataset and is using a 2nd order Butterworth filter to create expected standard deviations of wind output. This will be used for WWSIS2, pending verification of statistical properties.



	Day 1 Sigma	Day 2 Sigma	Day 3 Sigma
WECC	2491	1675	1664
Footprint	1048	778	745

Figure 2.2 Statistical Analysis Showing Data Seam at Hour 16 of Every Third Day

Retirement Scenarios

- All scenarios (including base case TEPPC 2020)
  - Probably use WECC TEPPC DWG projections
  - May need to add capacity if additional units are retired from TEPPC 2020 case
    - Gas CC added in locations where capacity is retired
- Sensitivity analysis on additional retirements for renewable scenarios
  - Amount retired will be based on capacity value of renewables

Startup/cycling costs

- Sensitivities
  - Default generic values from WECC assumptions
  - Minimum by category from APTECH results
  - Maximum by category from APTECH results (input data will not be made public)
  - Potentially one more scenario with a distribution of cycling costs from the APTECH estimates for each category, based on random assignment or independent variable (e.g., age)
- It is not important to get the correct cycling cost at the each unit – only that the general distribution is correct
  - Units that are projected to be cycled may be different from units that are actually cycled for various reasons
- Apply different cost for hot, warm, cold starts, and ramping penalties if necessary

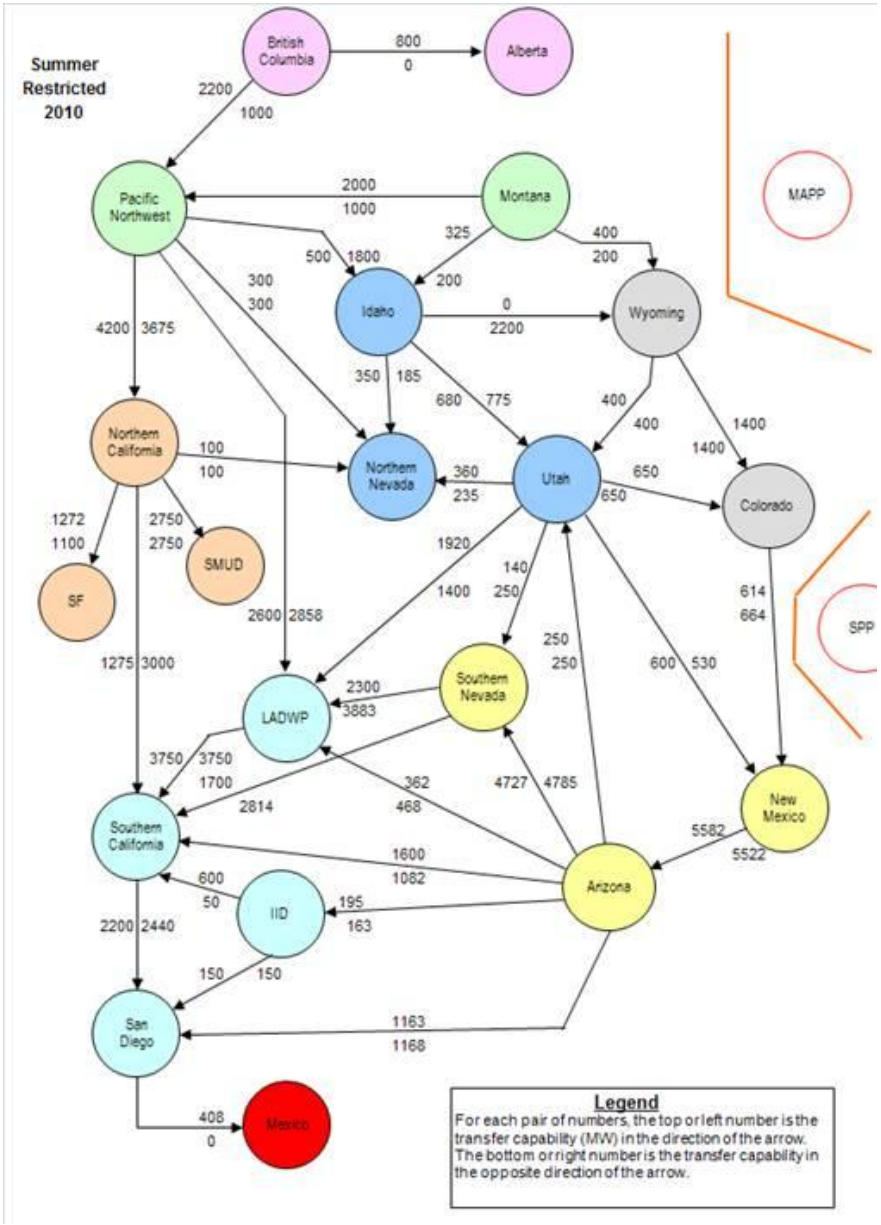
Smaller working groups

We will have smaller working groups on the following topics:

- Solar generation and forecast data creation
- Wind forecast error correction
- APTECH startup costs
  - How to apply distributions of generic data to specific units
  - NDAs required to see any information on distributions, but not to see minimum costs by category

Please let us know if you would like to be involved

Transmission zones



- Run zonally initially. Nodal runs at a later date for deeper dives.
- Propose to use these 20 TEPPC zones. Aiming at more rather than less zones to better approximate actual current operations.
- Commit and dispatch within each zone with no hurdle rates between zones to allow for interzone transfers.

Capacity (GW) by state for 3 scenarios

	HighWind			Intermediate			HighSolar		
	Wind	PV	CSP	Wind	PV	CSP	Wind	PV	CSP
AZ	4.3	4.8	4.0	1.4	9.5	9.5	0.2	14.5	9.7
CA	11.1	11.6	3.0	5.9	16.1	3.8	5.4	19.4	9.2
CO	5.5	2.5	0.2	3.9	2.6	0.2	3.0	5.1	1.3
ID	1.1	0.0	0.0	1.0	0.0	0.0	0.5	0.0	0.0
MT	5.9	0.1	0.0	4.0	0.1	0.0	1.0	0.1	0.0
NM	4.2	0.4	0.1	2.8	2.1	0.3	0.5	3.2	0.6
NV	2.8	0.9	0.6	1.4	4.1	0.6	0.2	6.6	0.6
OR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SD	2.3	0.0	0.0	1.9	0.0	0.0	0.3	0.0	0.0
TX	0.0	0.2	0.0	0.0	0.4	0.0	0.0	0.5	0.0
UT	1.1	0.9	0.0	0.6	2.2	0.0	0.3	4.9	0.0
WA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WY	9.0	0.0	0.0	6.8	0.0	0.0	1.5	0.0	0.0
Total	47.3	21.3	7.8	29.6	37.1	14.4	13.0	54.2	21.3

Wind Forecast Dataset

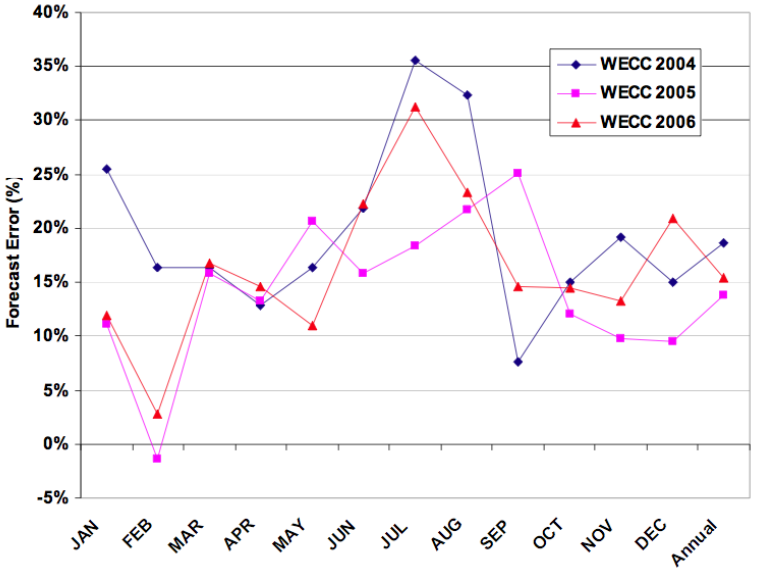
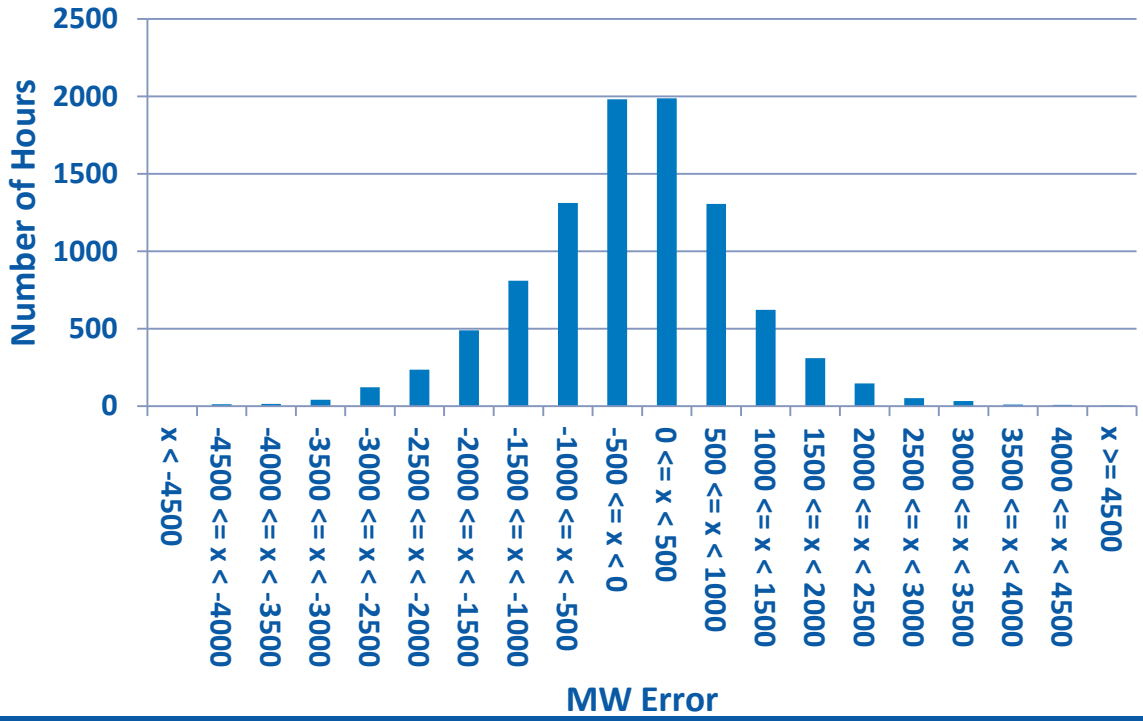


Figure 2.4 Monthly Wind Forecast Error in WECC

Western wind dataset has a positive bias in the day-ahead forecasts

Use measured wind forecast error distributions to correct bias



Solar “Actuals” Dataset

- Utility-scale PV
  - Existing WECC PV dataset has 50 MW PV plants modeled for 10km grid cells
  - Filter function under development to model utility-scale PV plants up to 500 MW. We will need to size and site these. Propose 50/50 split between metropolitan and remote areas.
- DG PV
  - Use DG rooftop PV dataset from WWSIS1
  - Distribute generation identical to load in each load bubble
- CSP
  - Rerun CSP profiles for 10 hours of storage
  - Select best sites

Solar Forecasts Dataset

- Obtaining solar forecast error distributions
- Check existing solar forecast dataset against measured forecast error distributions
- Refine existing solar forecast dataset as necessary to match measured distributions